Asian Journal of
Biological
Sciences

OPEN ACCESS

Effect of Soil Contaminated with Heavy Metals on the Nutrient Content of *Zea mays* L.

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ABSTRACT

Background and Objective: The toxicity of heavy metals varies depending on the plant variety, age, plant growth stage, concentration and type of heavy metals in the soil. The study aimed to evaluate the status of contamination with some heavy metals including (Pb, Cd, Co, Cr and Ni) and the effect of this on the content of the major nutritional elements (N, P and K) of *Zea mays* plant. **Materials and Methods:** Samples of contaminated soil were collected from the three plowed fields at two distances from the source of pollution (400 and 800 m) in the southeastern direction, which is the direction of the prevailing wind movement in the areas and at two depths (0-25 and 25-50 cm), in addition to the control treatment (uncontaminated). The heavy metals were estimated and their contaminated standards were calculated. The plant was grown in plastic pots, each with a capacity of 6 kg. **Results:** The results showed that the concentrations of heavy metals (Pb, Cd, Co and Ni) (except Cr) in the soil of the Al-Ahadab, Badra and Al-Gharaf increased more than the internationally permissible limits, especially at a distance of 400 m at a depth of 0-25 cm. However, the concentrations of the metals were highest values in Al-Ahdab field for all dimensions and depths compared to the Badra and Al-Gharraf oil fields. **Conclusion:** The pollution load index (PLI) indicated a deterioration in the soil of the study, especially the sites close (400) m compared to 800 m away at a depth of 25-50 cm.

KEYWORDS

Contaminated soil, heavy metals, nutrient content, *Zea mays*, pollution load index

INTRODUCTION

The world looks with concern and interest at the large and increasing quantities of toxic substances that the soil receives because of the danger these substances pose to human health[1]. There are more than one million tons/year of toxic chemicals from factories that pollute soil, water and air[2]. The effects of soil pollution include bad effects on human, plant and animal health, damage to buildings built on them and contamination of groundwater and surface water[3]. Pollution occurs only when the concentration of pollutants in the soil as a result of human activity becomes greater than the natural concentration of these substances in the soil. This concentration has a bad effect on the environment and its elements. From the point of view of human, animal and plant health, the soil is not considered polluted unless the concentration of pollutants in it reaches a critical limit at which vital processes are affected[4,5].

Diagnosing pollution requires evaluating the pollutants at the pollution sites, including the size of the pollutants in relation to the volume of the soil, as well as the distribution of these pollutants in the soil and

ISSN: 1996-3351 (Print)
https://doi.org/10.3923/ajbs.2024.535.547

Received: 06 Apr. 2024
Accepted: 21 May, 2024
Published: 31 Dec. 2024

the chemical physical and biological properties of each pollutant and the interaction of these pollutants with the soil[3,6]. They are caused by the action of several compounds, including heavy metals that are toxic to humans, plants and animals such as lead, cadmium, zinc, chrome and copper[7]. In addition, some organic pollutants such as oils, solvents and petroleum derivatives, the misuse of pesticides and the misuse of chemical and organic fertilizers that used to increase agricultural production[8,9].

Plants are the first link in the chain of living organisms that are affected by heavy metals[10]. The effect of heavy metals on plants is toxic. If its concentration exceeds the permissible limits, this leads to the inhibition of plant growth and the unpreparedness of the nutrients necessary for its growth, thus reducing its productivity[11]. In addition, its transmission through the human food chain causes cancerous diseases[12].

The toxicity of heavy metals varies depending on the plant variety, age, plant growth stage, concentration and type of heavy metals in the soil[13]. In addition, to differences in solubility, absorption, transport and chemical activity of the heavy metals[14]. The readiness of heavy metals in the soil and their absorption by plants does not depend only on the readiness of nutrients but also depends on the diversity of interfering plant and soil factors, such as the type of clay and organic matter in the soil, the degree of soil interaction, the type of plant and the variety and age of the plant[15].

Therefore, this study aims to evaluate the level of soil contamination with heavy metals such as lead, cadmium, cobalt and chromium produced by several oil companies. As well as know the effect of these heavy metals on the readiness of the necessary nutrients and the growth of *Zea mays* plants.

MATERIALS AND METHODS

Study areas: The study was carried out from April, 2022 to September, 2023. The study included the areas surrounding the following oil fields:

- Badra oil field in Wasit Province
- Al-Ahdab oil field in Wasit Province
- Al-Gharraf oil field in Dhi Qar Province

Soil samples were collected on 6/1/2023 from the southeastern part of each field, in the direction of the prevailing wind movement in the areas and at two distances of 400 and 800 m from the source of pollution for each field, at two depths (0-25 cm) and 25-50 cm. Three samples for each site and dimension. The soil samples were air-dried, ground and sieved with a 2 mm sieve. Some chemical and physical characteristics of the soil of each site were estimated, as shown in Table 1.

Chemical and physical soil analyses: The degree of soil reaction (pH): It was measured with a pH-meter in a soil: Water suspension (1:1) according to Emmerich *et al.*[16].

Electrical conductivity EC: It was measured with an EC-meter in a soil: Water suspension (1:1) according to Emmerich *et al.*[16].

Dissolved positive and negative ions

Calcium and magnesium: Calcium and magnesium ions in the soil were determined by stripping according to the method described by Richards[17].

Sodium and potassium: Sodium and potassium ions were estimated using a Flame Photometer as described by Emmerich *et al.*[16].

Table 1: Some chemical and physical characteristics of the study soil

				(%)				Dissolved ions (mmol/L)							
Site	Depth (cm)	PH	EC (ds/m)	Clay	Sand	Silt	Soil texture	SO_4^-	Mg^{2+}	CO_3	Ca^{2+}	K	Cl^-	Na	HCO^{-3}
Al-Ahadab	0-25	7.13	6.2	41.1	40.6	18.9	Silty clay	17.4	7.50	Nil	7.81	1.32	30.32	282.1	1.5
	25-50	7.12	5.5	46.3	38.6	17.8	Silty clay	16.4	6.5	Nil	8.32	0.43	29.32	310.4	2.1
Badra	0-25	7.64	6.50	43.4	44.4	18.6	Silty clay	18.3	6.00	Nil	6.32	0.78	28.14	311.4	3.6
	25-50	7.41	4.50	44.2	43.3	15.9	Silty clay	17.9	7.40	Nil	6.72	1.45	27.92	291.4	2.5
Al-Gharaf	0-25	7.45	6.68	45.1	36.7	17.8	Silty clay	23.2	5.70	Nil	7.12	1.05	29.61	323.8	4.3
	25-50	7.34	5.25	42.6	41.4	14.8	Silty clay	22.4	6.80	Nil	6.32	1.54	33.4	297.3	3.1

Chloride ion: Chloride ions were estimated using the cross-section method and according to the method proposed by Jackson[18].

Sulfate ion: Sulfate ions were measured using the turbidity method using a spectrophotometer according to Emmerich *et al.*[16].

Carbonate and bicarbonate ions: It was measured using a titration method with diluted sulfuric acid, according to Richards[17].

Soil texture: The hydrometer method was used to determine the size distribution of clay, sand and silt according to the method described by Black and Power[19].

Estimation of heavy metals in soil: Heavy metals in the soil (Pb, Cd, Cr and Cu) were determined by the wet digestion method using a mixture of H_2SO_4+$HCLO_3$ and measured with an Atomic Absorption Spectrophotometer, according to Davies *et al.*[20].

Calculating indicators of soil environmental pollution

Contamination factor (CF): It was calculated using the method of Bazzaz *et al.*[21] as follows:

CF	=	Cm sample/Cm background
CF	=	Pollution factor
Cm sample	=	Total concentration of the heavy metal in the soil (mg/kg)
Cm background	=	Total concentration of the heavy metal in the comparison soil sample (mg/kg)

Pollution load index (PLI): It was calculated using the method of Hakanson[22] as follows:

$$PLI = (CF1*CF2*CF3*...*CFn)1/n$$

where, PLI is pollution load index, CF is pollution factor for the first, second, etc., elements and n is the number of heavy metals studied.

Geo accumulation index (Igeo): It was calculated using the method of Müller *et al.*[23] and my agencies:

$$Igeo = \log 2 \times \frac{Cmetal}{1.5 \times control}$$

Where:

Igeo	=	Index of geological accumulation
Cmetal	=	Concentration of heavy metal in soil
Control	=	Concentration of the heavy metal in the comparison sample
1.5	=	Geological impact factor

Agricultural experience: The agricultural experiment was applied in plastic pots with a capacity of 8 kg each in Wasit Province, by placing 6 kg of air-dry soil taken from the surrounding areas of three oil fields: Al-Ahdab oil field, Badra oil field and Al-Gharraf oil field. On 7/15/2023, seeds of corn plants (Bohouth 106) were planted in plastic pots at a rate of 15 seeds per pot and then they were reduced to five plants after germination. Soil moisture was maintained to the limits of field capacity by daily weighing these anvils. The plants were moved from the soil surface level 60 days after germination. The plants were dried at a temperature of 70°C and the dry weight of the plant was calculated.

The dry samples were ground, sieved and digested according to the method of Cresser *et al.*[24] and the concentrations of N, P and K in the digestion solution were estimated. The absorbed amount of each metal was then calculated by multiplying the dry weight of the plant and the concentration of the metal in the plant.

Statistical analysis: The experiment in this study was analyzed using a Completely Randomized Design (CRD) with three replications. The characteristics were analyzed using analysis of variance using the Gen Stat Discovery program. The averages of the coefficients were compared using the least significant difference (LSD) at the probability of 0.05.

RESULTS AND DISCUSSION

Total concentration of heavy metals in the study soil

Total lead (mg/Pb/kg soil): The results show the values of total lead in three sites with soil contaminated with heavy metals as a result of gas emissions. They are Al-Ahdab oil field, Badra oil field and Al-Gharraf oil field, at different dimensions and two depths (Table 2). The highest value of total lead was achieved in the Ahdab oil field, which was 337.88 mg/Pb/kg soil at a distance of 400 m compared to the Badra and Al-Gharaf oil fields, for which the values reached 290.28 and 257.75 mg/Pb/kg soil, respectively, for the same distance (Table 2). However, the lowest values were achieved at a distance of 800 m, reaching 180.32, 160.22 and 142.89 mg/Pb/kg soil for Al-Ahdab, Badra and Al-Gharaf oil fields, respectively, while depths 0-25 cm achieved the highest amount of total lead. It was 50.87 and 48.97 mg/Pb/kg soil for the depths 0-25 and 25-50 cm, respectively.

The bilateral interaction between dimension and depth showed a significant effect on the amount of total lead in the soil of the study. The highest value was achieved in the Al-Ahdab oil field at a distance of 400 m at a depth of 0-25 cm, which amounted to 345.60 mg/Pb/kg soil compared to the Al-Gharraf field, which achieved the lowest value at a distance of 800 m at a depth of 25-50 cm, which was 135.39 mg/Pb/kg soil. The results of the study also showed that the values of total lead in oil field soil were higher than the internationally permissible limit, which was 100 mg/Pb/kg soil.

This is due to the proximity of these sites to the oil industrial activity represented by extractive wells, isolation stations and oil incinerators, which release their waste directly into the surrounding environment, causing the accumulation of heavy elements in the soil, including lead[7,25].

Total cadmium (Cd): The results showed the total cadmium in the soil of the study, which showed a clear variation depending on the location, distance from the source of pollution and depth (Table 3). The highest value was achieved in the Al-Ahdab oil field at a distance of 400 m from the source of pollution, which was 10.43 mg/Cd/kg soil, compared to the Badra and Al-Gharaf oil fields, at the same distance of 400 m, where their values reached 9.38 and 8.25 mg/Cd/kg soil, respectively. However, the distance of 800 m from the source of pollution achieved a lower amount of total cadmium compared to the distance of 400 m, which amounted to 5.33, 4.03 and 5.50 mg/Cd/kg soil for the site of Al-Ahdab, Badra and Al-Gharaf, respectively, but the quantities achieved were higher than the control treatment, which recorded 1.21 mg/Cd/kg soil. This is due to the gases emitted from oil extraction and refining, which over time lead to the accumulation of heavy elements in the soil, especially in areas near oil fields.

The depth of 0-25 cm showed higher values of total cadmium. It was 1.25 mg/Cd/kg soil, compared to the depth of 25-50 cm, which showed a lower value (1.18) mg/Cd/kg soil. The results of the statistical analysis (Table 3) indicated the presence there was a significant effect on the values of total cadmium in the soil for both dimension and depth, while the two-way interaction between dimension and depth was insignificant at the 0.05 probability level[8,9].

Table 2: Total lead concentration (mg/Pb/kg soil) in the soil

		Depth (cm)		
Site	Distance of pollution (m)	0-25	25-50	Average
Al-Ahadab	400	345.60	330.15	337.88
	800	190.46	170.18	180.32
Badra	400	300.00	280.55	290.28
	800	170.22	150.22	160.22
Al-Gharaf	400	270.11	245.39	257.75
	800	150.39	135.39	142.89
Control		50.87	48.97	49.92
Average		211.09	193.84	
LSD 0.05		Distance	Depth	Distance×depth
		35.26	15.00	14.38
Global limitations WHO, 2007[25]			100 mg/kg soil	

Table 3: Total cadmium concentration (mg/Cd/kg soil) in the soil

		Depth (cm)		
Site	Distance of pollution (m)	0-25	25-50	Average
Al-Ahadab	400	11.00	9.85	10.43
	800	5.66	5.00	5.33
Badra	400	10.00	8.75	9.38
	800	4.78	3.28	4.03
Al-Gharaf	400	9.24	7.25	8.25
	800	6.45	4.55	5.50
Control		1.25	1.18	1.21
Average		6.91	5.66	Distance×depth
LSD 0.05		Distance	Depth	
		3.00	0.25	ns
Global limitations WHO, 2007[25]			3 mg/kg soil	

Table 4: Total nickel concentration (mg/Ni/kg soil) in the soil

		Depth (cm)		
Site	Distance of pollution (m)	0-25	25-50	Average
Al-Ahadab	400	116.50	98.56	107.53
	800	65.34	51.37	58.36
Badra	400	103.57	87.36	95.47
	800	77.26	59.16	68.21
Al-Gharaf	400	95.37	78.47	86.92
	800	66.44	48.89	57.67
Control		12.76	11.58	12.17
Average		76.75	61.48	Distance×depth
LSD 0.05		Distance	Depth	
		15.23	11.11	ns
Global limitations WHO, 2007[25]			50 mg/kg soil	

ns: No significant differences

Total nickel (Ni): The results recorded that total nickel in the soil of the studied oil fields contaminated with heavy metals, including nickel showed a clear variation according to the study sites, distance from the source of pollution and depth. The highest values were recorded at the distance of 400 m, which amounted 107.53, 95.47 and 86.92 mg/Ni/kg soil for the sites of Al Ahdab, Badra and Al Gharaf, respectively, compared to the distance of 800 m, which recorded lower values, which were 58.36, 68.21 and 57.67 mg/Ni/kg. As -1 soil for the studied fields. However, the values achieved for the oil fields of the two dimensions were higher than the comparison values, which amounted to 12.17 mg/Ni/kg soil (Table 4).

Table 5: Total cobalt concentration (mg/Ni/kg soil) in the soil

		Depth (cm)		
Site	Distance of pollution (m)	0-25	25-50	Average
Al-Ahadab	400	65.23	47.77	56.50
	800	32.33	19.57	25.95
Badra	400	70.00	50.45	60.23
	800	34.12	18.67	26.40
Al-Gharaf	400	50.26	25.37	37.82
	800	25.33	17.60	21.47
Control		5.77	4.75	5.26
Average		40.43	25.99	Distance×depth
LSD 0.05		Distance	Depth	
		4.00	10.25	ns
Global limitations WHO, 2007[25]			10 mg/kg soil	

ns: No significant differences

The results of the study showed that the values achieved at a depth of 0-25 cm were 76.75 mg/Ni/kg soil, which is higher than the values achieved at a depth of 25-50 cm and reported 61.48 mg/Ni/kg soil. The results obtained were higher than the limits. The internationally permitted limit was 50 mg/Ni/kg soil. This is due to the reasons mentioned previously. The results of the statistical analysis (Table 4) indicated a significant effect for both dimension and depth and an insignificant effect for the interaction between dimension and depth[13,14].

Total cobalt (Co): Table 5 shows the values of total cobalt in the soil of the areas surrounding the oil fields in the soil of the study. The study showed that the highest values were recorded in the soil of the first dimension of the pollution source (400) m, which amounted to 56.50, 60.23 and 37.82 mg/Co/kg in the soil of the sites. Al-Ahdab, Badra and Al-Gharaf, respectively, compared the soil of the second dimension from the source of pollution (800) m, which achieved lower values than the first dimension. It reached 25.95, 26.40 and 21.47 mg/Co/kg soil, respectively (Table 5). However, the values obtained were higher than the comparison treatment, which recorded 5.26 mg/Co/kg soil. The results of the statistical analysis (Table 5) indicated a significant effect for both dimension and depth, while the differences were not significant for the interaction between dimension and depth.

Total chromium (Cr): Table 6 shows the values of total chromium in the studied sites. The results showed that the highest values were recorded at the first distance from the source of pollution (400) m for all the school sites, as the values reached 86.51, 90.35 and 68.20 mg/Cr/kg soil for the Al-Ahadab and Badra sites. and Al-Gharaf, respectively, compared to the second dimension (800) m, which achieved lower values, reaching 39.69, 56.96 and 31.45 mg/Cr/kg soil, respectively,. These values were higher in the comparison treatment, which amounted to 5.78 mg/Cr/kg soil. The values at the depth of 0-25 cm were higher than the values at the depth of 25-50 cm. They reached 60.72 and 47.40 mg/Cr/kg soil for the two depths, respectively. The values obtained were less than the permissible limits. Globally was 200 mg/Cr/kg soil. The results of the statistical analysis (Table 6) indicated that there is a significant effect between both dimension and depth and a non-significant effect for the interaction between dimension and depth[3,4].

Pollution indicators for heavy metals in the study soils

Ccontamination factor (CF): The pollution factor values for the heavy metals studied in the oil fields (Al-Ahdab, Badra, Al-Gharraf) for the metals (Pb, Cd, Cr, Ni and Co) were studied. The results of the study showed that the highest values for the contamination factor with lead, cadmium, chromium, nickel and cobalt were at the Al-Ahhab site at a depth of 0-25 cm at a distance of 500 m, which were to 6.79, 8.80, 15.93, 9.13 and 11.31, respectively (Table 7).

Table 6: Total cobalt concentration (mg/Ni/kg soil) in the soil

		Depth (cm)		
Site	Distance of pollution (m)	0-25	25-50	Average
Al-Ahadab	400	95.63	77.39	86.51
	800	45.69	33.69	39.69
Badra	400	100.00	80.69	90.35
	800	65.22	48.69	56.96
Al-Gharaf	400	75.00	61.39	68.20
	800	37.50	25.39	31.45
Control		6.00	5.56	5.78
Average		60.72	47.40	Distance×depth
LSD 0.05		Distance	Depth	
		18.52	13.00	ns
Global limitations WHO, 2007[25]			200 mg/kg soil	

ns: No significant differences

Table 7: Contamination factor (CF) values for heavy metals in the study soils

Depth (cm)	Site	Distance (m)	Pb	Cd	Cr	Ni	Co
0-25	Al-Ahadab	400	6.79	8.80	15.93	9.13	11.31
		800	3.74	4.53	7.62	5.12	5.60
	Badra	400	5.90	8.00	16.67	8.12	12.13
		800	3.35	3.82	10.87	6.05	5.91
	Al-Gharaf	400	5.31	7.39	12.50	7.47	8.71
		800	2.96	5.16	6.25	5.21	4.39
25-50	Al-Ahadab	400	6.74	8.35	13.92	8.51	10.06
		800	3.48	4.24	6.06	4.44	4.12
	Badra	400	5.73	7.42	14.51	7.54	10.62
		800	3.07	2.78	8.76	5.11	3.93
	Al-Gharaf	400	5.01	6.14	11.04	6.78	5.34
		800	2.76	3.86	4.57	4.22	3.72
Bazzaz *et al.*[21]			CF<1	3>CF>1	6>CF>3		CF>6

However, the Al-Gharraf site at a depth of 25-50 cm at a distance of 800 m, achieved the lowest values for the contamination factor with lead, cadmium, chromium, nickel and cobalt, which amounted to 2.76, 3.86, 4.57, 4.22 and 3.72, respectively. It indicates the occurrence of very severe pollution with the elements lead, cadmium, chromium, nickel and cobalt for all the studied sites at a distance of 500 m and a depth of 0-25 cm[21] (CF>6) and moderate pollution (CF>3>1) to severe pollution (6>CF>3) in the second dimension (800 m), especially at a depth of 25-50 cm.

This is due to the high concentration of heavy metals in the soil near the studied sites as a result of transportation movement and oil activity. The combustion processes of gases accompanying the oil extraction process and the accumulation of heavy metals in sites close to the source of pollution[19]. Al-Ahdab oil site achieved the highest values for the heavy metal pollution factor compared to the Badra and Al-Gharf oil sites.

Pollution load index (PLI): This indicator expresses the status of pollution of the soil in a specific location. The results of Table 8 indicate the variation in the values of the pollution index (PLI) for the heavy metals studied (lead, cadmium, chromium, nickel and cobalt). The highest values of the pollution load index were recorded at the Al-Ahhab site at a depth of 0-25 cm at a distance of 400 m, which was 9.97 mg/kg, compared to the Al-Gharraf site at a depth of 25-50 cm and at a distance of 800 m, which recorded the lowest values, as it reached 3.77 mg/kg. It is noted from the results of the study that the soils of the sites of Al Ahdab, Badra and Al Gharraf are in a state of deterioration (PLI>1). This is due to the gases and vapors emitted from the oil fields studied as a result of oil extraction operations, which contain quantities of heavy metals.

Table 8: Pollution load index values for heavy metals in the study soils

		Depth (cm)	
Site	Distance	0-25	25-50
Al-Ahadab	400	9.97	9.23
	800	5.17	4.39
Badra	400	9.50	8.68
	800	5.49	4.32
Al-Gharaf	400	7.96	6.58
	800	4.65	3.77
PLI	1>PLI	PLI =1	PLI>1
	Non-pollution	Verge of deterioration	Deterioration of site quality

Table 9: Geological accumulation index values for heavy metals in the study soils

Depth (cm)	Sites	Distance (m)	Pb	Cd	Cr	Ni	Co
0-25	Al-Ahadab	400	2.00	2.24	2.74	2.26	2.46
		800	1.48	1.66	2.10	1.76	1.84
	Badra	400	1.88	2.14	2.78	2.16	2.52
		800	1.40	1.50	2.42	1.92	1.88
	Al-Gharaf	400	1.80	2.08	2.54	2.08	2.22
		800	1.28	1.76	1.94	1.78	1.62
25-50	Al-Ahadab	400	2.00	2.18	2.62	2.20	2.34
		800	1.42	1.60	1.90	1.64	1.58
	Badra	400	1.86	2.08	2.66	2.10	2.40
		800	1.32	1.24	2.22	1.76	1.54
	Al-Gharaf	400	1.74	1.92	2.42	2.00	1.80
		800	1.22	1.52	1.66	1.60	1.48
Stoffers *et al.*[26]		I<0	0<I<1	I<I<2	2<I<3	4<I<5	I<6

Geological accumulation index: Table 9 shows the values of the geological accumulation index of the heavy elements studied in the soils of the Al-Ahdab, Badra and Al-Gharf oil sites at two depths: The highest geological accumulation index was achieved at the Al-Ahkab site at a depth of 0-25 cm at a distance of 400 m, which reached 2.00, 2.24, 2.74, 2.26 and 2.46 mg/kg for the metals lead, cadmium, chromium, nickel and cobalt, respectively, which indicates that the Al-Ahkab site at this distance and depth is moderate[26] (2<I<3). However, the Gharraf oil field at a depth of 25-50 cm at a distance of 800 m, achieved the lowest values, which amounted to 1.22, 1.52, 1.66, 1.60 and 1.48 mg/kg for the metals including lead, cadmium, chromium, nickel and cobalt, respectively. It indicates that the Gharraf field is at a depth of 25-50 cm and a distance of 800 m it falls within moderate pollution limits (I<I<2)[26].

Plant indicators

Dry weight of the plant (gm/kg/dry): The results show the dry weight of the Durrat Al-Safara plant for Al-Ahdab, Badra and Al-Gharaf oil sites on soils contaminated with heavy metals at two different distances and depths. The results showed that the values differed according to the location, dimension and depth, as the first dimension (400 m) achieved the lowest values for all the studied sites, which were 150.70, 183.69 and 205.35 g/kg/dry for the Al-Ahdab, Badra and Al-Gharaf sites, respectively, compared to the dimension. The second (800 m) achieved higher values than the first dimension, which were 175.50, 201.75 and 219.59 g/kg/dry matter for the Al-Ahadab, Badra and Al-Gharaf sites, respectively (Table 10). This is due to the high concentrations of heavy metals in the nearby sites (400 m), resulting from gas emissions and oil extraction (Table 2-6), compared to the distant sites (800 m), which contain smaller quantities of heavy metals, which leads to deterioration. The soil reduces the plant's absorption of nutrients such as N, P and K and thus leads to a decrease in dry weight.

It is also noted that the dry weight at the Al-Ahdab site decreased significantly compared to the Badra and Al-Gharaf sites. This is due to the increased concentrations of heavy metals such as (Pb, Cd, Co, Cr and Ni)

Table 10: Dry weight (g/kg dry) of the plant grown in the study soil

Site	Distance	Depth		Average
Al-Ahadab	400	143.11	158.29	150.70
	800	168.00	183.00	175.50
Badra	400	178.78	188.60	183.69
	800	190.37	213.13	201.75
Al-Gharaf	400	195.33	215.37	205.35
	800	211.00	228.17	219.59
Average		181.10	197.76	
Control		271.39	266.57	268.98
LSD 0.05		Distance	Depth	Distance×depth
		7.53	10.00	ns

ns: No significant differences

in the Al-Ahdab soil compared to the other sites. However, the control treatment (unpolluted) achieved the highest values in the dry weight of the plant. It has recorded 268.98 g/kg dry. It is due to the comparison soil not containing heavy metals, which helped increase the readiness of nutritional elements, improves plant growth and increases its dry weight. The results of the study (Table 10) also showed that the dry weight at a depth of 25-50 cm achieved the highest values, which amounted to 197.76 g/kg for all studied sites. This is due to the fact that the depth of 0-25 cm contains higher concentrations of heavy elements, which leads to a lack of readiness for major nutritional elements and thus a decrease in dry weight compared to the depth of 25-50 cm, which contains the least amount of heavy elements and thus an increase in the dry weight of the plant.

It is also noted that the dry weight in the comparison treatment was higher than that of the oil sites, reaching 271.39 and 266.57 g/kg/dry matter for the depths 0-25 and 25-50 cm, respectively. Also, the dry weight value in the comparison treatment was at the depth of 0-25. cm. The highest comparison treatment was at a depth of 25-50 cm. This is due to the surface layer containing organic materials, the necessary nutritional elements and aeration conditions that encourage the readiness of nutrients, improve plant growth and increase its dry weight. The results of the statistical analysis indicated that there was a significant effect of both distance from the source of pollution and depth on the dry weight of the yellow iris plant, while the effect was not significant for the bilateral interaction between distance and depth on the dry weight values of the plant.

Concentrations of nutrients in plants (%): Table 11 shows the concentration of nutrients in the plant. The results showed a difference in the concentrations of N, P and K depending on the location, distance from the source of pollution and depth.

The highest value was achieved at the Al-Gharraf site, at a distance of 800 m, at a depth of 25-50 cm, which amounted to 0.750, 0.070 and 0.760% for nitrogen, phosphorus and potassium, respectively, with a general average of 0.527%, compared to the Al-Ahdab oil field, which recorded the lowest values at a distance of 400 m at a depth of 0-25 cm, the values reached 0.110, 0.010 and 0.130% for nitrogen, phosphorus and potassium, respectively, with a general average of 0.083%. The reason for the decrease in the concentrations of nutrients in plants at the Al-Ahdab site is due to the high concentrations of heavy elements (Pb, Cd, Co, Cr and Ni) in the Al-Ahdab soil, which caused soil deterioration, reduced the availability of nutrients and led to a decrease in the concentrations of nutrients and dry weight (Table 10) compared to the two Al-Gharraf sites And Badra Al-Nafititain. The distance of 800 m achieved the highest amount of nutritional elements compared to the distance of 400 m for all the sites studied.

This is due to the fact that nearby locations are more polluted than distant locations due to the density of gases emitted from oil activities and oil extraction. However, the comparison soil achieved the highest

Table 11: Concentration of nutrients in plants growing in study soils contaminated with heavy metals

			(%)			
Depth (cm)	Site	Distance	N	P	K	Average
0-25	Al-Ahadab	400	0.110	0.010	0.130	0.083
		800	0.150	0.020	0.180	0.117
	Badra	400	0.300	0.030	0.250	0.193
		800	0.380	0.040	0.340	0.253
	Al-Gharaf	400	0.560	0.040	0.430	0.343
		800	0.640	0.050	0.520	0.403
25-50	Al-Ahadab	400	0.220	0.030	0.570	0.273
		800	0.310	0.050	0.610	0.323
	Badra	400	0.430	0.050	0.650	0.377
		800	0.570	0.060	0.700	0.443
	Al-Gharaf	400	0.620	0.060	0.720	0.467
		800	0.750	0.070	0.760	0.527
Average			0.420	0.043	0.488	
Control			1.000	0.090	0.790	0.627
LSD 0.05			Distance	Depth	Distance×depth	
			0.010	0.1	0.01	

ns: No significant differences

Table 12: Quantity of nutrients absorbed by plants growing in study soils contaminated with heavy metals

			(%)			
Depth (cm)	Site	Distance	N	P	K	Average
0-25	Al-Ahadab,	400	15.74	1.43	18.60	11.93
	800	25.20	3.36	30.24	19.60	
	Badra	400	53.63	5.36	44.70	34.56
	800	72.34	7.61	64.73	48.23	
	Al-Gharaf	400	109.38	7.81	83.99	67.06
	800	135.04	10.55	109.72	85.10	
25-50	Al-Ahadab,	400	34.82	4.75	90.23	43.27
	800	56.73	9.15	111.63	59.17	
	Badra	400	81.10	9.43	122.59	71.04
	800	121.48	12.79	149.19	94.49	
	Al-Gharaf	400	133.53	12.92	155.07	100.51
	800	171.13	15.97	173.41	120.17	
Average			84.18	8.43	96.17	62.93
Control			271.39	24.43	214.40	170.07
LSD 0.05			Distance	Depth	Distance×depth	
				9.00	8.00	ns

ns: No significant differences

concentrations of nutrients in plants, which amounted to 0.627% compared to all locations and dimensions studied. This is due to the fact that the comparison soil is not contaminated with heavy elements, which reflected positively on increasing the readiness of nutrients and improving plant growth. As for depth, the depth of 25-50 cm achieved high values of concentrations of nutritional elements compared to the depth of 0-25 cm. This is due to the fact that the surface depth of 0-25 contains high concentrations of heavy elements compared to the subsurface depth (25-50 cm), which reduces the readiness of nutrients and thus their concentration in the plant. The results of the statistical analysis indicated a significant effect for both dimension and depth and the interaction between them (Table 11).

Table 12 shows the amount of nutrients in the plant grown in the study soil contaminated with heavy metals, except for the control soil (not contaminated). The results of the study showed that the lowest absorbed amount was recorded at the Al-Ahhab site, 400 m away, at a depth of 0-25 cm, which amounted to 15.74, 1.43 and 18.60 mg/kg/dry for N, P and K, respectively, with an overall average of 11.93 mg/kg/dry matter compared to the amount in the Gharraf oil field, which recorded higher values at a distance of 800 m at a depth of 25-50 cm, which amounted to 171.39, 15.97 and 173.41 mg/kg/dry for N, P and K, respectively, at a rate In general, it reached 120.17 mg/kg/dry.

This is due to the fact that the areas near (400 m) from the studied oil fields contain the highest amount of heavy elements, which limit the plant's ability to absorb nutrients, compared to the areas far away (800 m), which contain lower concentrations of heavy metals and thus the absorbed amount of nutrients increases. However, the comparison treatment achieved the highest amount absorbed compared to the oil fields, which amounted to 271.39, 24.43 and 214.40 mg/kg/dry for N, P and K, respectively, with a general average of 170.07 mg/kg/dry. The reason is that the soil. The control treatment was not contaminated with heavy metals and thus the absorbed amount of nutrients in the plant increased. In general, the absorbed quantity of nutrients at a depth of 25-50 cm was higher than at a depth of 0-25 cm. This is due to the lack of heavy elements contained in the subsurface depth compared to the surface depth and thus the absorbed quantity increased. The results of the statistical analysis indicated Table 12 There was a significant effect for both dimension and depth and an insignificant effect for the interaction between them.

CONCLUSION

The study concludes that the concentrations of heavy metals (Pb, Cd, Co and Ni) (except Cr) in the soil of the Al-Ahadab, Badra and Al-Gharaf increased more than the internationally permissible limits, especially at a distance of 400m at a depth of 0-25 cm. The variation in the values of the pollution index (PLI) for the heavy metals studied (lead, cadmium, chromium, nickel and cobalt). The highest values of the pollution load index were recorded at the Al-Ahhab site at a depth of 0-25 cm at a distance of 400 m.

SIGNIFICANCE STATEMENT

The toxicity of heavy metals varies depending on the plant variety, age, plant growth stage, concentration and type of heavy metals in the soil. The heavy metals were estimated and their contaminated standards were calculated. The plant was grown in plastic pots, each with a capacity of 6 kg. The results showed that the concentrations of heavy metals (Pb, Cd, Co and Ni) (except Cr) in the soil of the Al-Ahadab, Badra and Al-Gharaf increased more than the internationally permissible limits, especially at a distance of 400 m at a depth of 0-25 cm. However, the concentrations of the metals were highest values in the Al-Ahdab field for all dimensions and depths compared to the Badra and Al-Gharraf oil fields.

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